Solidification of II–VI Compounds in a Rotating Magnetic Field

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The primary aim of this work is to study the effects of a rotating magnetic field (RMF) on fluid flow and solidification of semiconductor compounds such as mercury cadmium telluride (HgCdTe) and cadmium telluride alloys. Control of the liquid boundary layer close to the solidifying interface has always been and continues to be of paramount interest to material scientists. The solid product is extremely susceptible to the behavior of such a layer and properties such as composition, defect concentration, precipitates and grain selection and twinning are dependent on the physical nature of the boundary layer. In Earth-based solidification, buoyancy driven convection and resultant fluid flows play a major role in establishing such a layer; indeed many of the flight projects involving solidification have had as their major objective the establishment of diffusion controlled solidification where the fluid flow becomes an insignificant contributor to compositional redistribution in the molten alloy.

The objective of the RMF is exactly the opposite. Fluid flow is encouraged and established by the interaction of the rotating magnetic field with the electrically conducting melt. The resulting flow cells prevent the formation of any kind of boundary layer and the material transport in the liquid can be controlled by the strength and frequency of the applied magnetic field. In practice, field strengths of the order of mT are required. Several advantages can be obtained from replacing the boundary layer. Transport of the alloy species through the melt is increased by using fluid flow rather than diffusion so that controlled solidification can be more rapid. The liquid-solid interface is more stable both from a temperature and a compositional standpoint. This stability prevents the oscillating temperatures which can give rise to the formation of inclusions. Indeed, in early work on a Soviet flight, a dramatic improvement in inclusion content was realized when the RMF was switched on midway through the flight.

Due to the nature of the process of solidifying alloys as compared to elements, it is necessary to solidify from a zone to make full use of the controlled stirring capability of the RMF. The zone enables complete replenishment of the solute component and thus permits the production of a uniform composition alloy. The types of solidification which will be studied are float zone, and the traveling solvent zone, or traveling heater method (THM). In this program, the float zone research will primarily be the responsibility of the University of Freiburg in Germany, while the THM work will be concentrated at MSFC. The alloy chosen for the MSFC study is the alloy of 80 percent HgTe and 20 percent CdTe, grown from a tellurium-rich zone. This alloy is strategically important as a sensor material, it is extremely difficult to grow with uniform properties, and it complements ongoing approved flight experiments for the United States Microgravity Payload missions (USMP–2 and USMP–4). Conventional THM work on Earth has been able to produce high, but not premium, quality HgCdTe material. Problems have included the incorporation of tellurium inclusions, the presence of low-angle grain boundaries, and the tendency for the composition to be non-uniform, particularly close to the edges of the wafer. All of these are deleterious to the production of large-scale arrays of detector devices. Control of the fluid flow close to the solidifying front will result in a degree of thermal and transport stability which will alleviate many of the difficulties associated with conventional THM.

Initial modeling of the process has shown that the interaction of the RMF with natural convection makes the interpretation of flow fields difficult to assess. It is thus important that microgravity experiments be undertaken to verify models. This we propose to do early in the program. Concurrent with this we shall grow THM HgCdTe both with and without the application of the RMF and fine tune the parameters. This work will be done concurrently and in close cooperation with modeling efforts to understand the role of the rotating magnetic field and the interaction of the field with the solvent zone both under terrestrial conditions and in a microgravity environment. From these results, we anticipate defining a flight experiment to verify the science of the technique.

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Biographical Sketch: Dr. Donald Gillies has been at MSFC working primarily on crystal growth and characterization of II-VI compounds. Prior to that, he spent 5 years at McDonnell Douglas Microelectronics Center in charge of liquid phase epitaxy production of detector grade mercury cadmium telluride.